ENERGY CONSUMPTION

CHINA'S FAST GROWING ECONOMY WILL CAUSE ENERGY CONSUMPTION TO INCREASE EXPONENTIALLY

A. INTRODUCTION

Recent Chinese energy history suggests four trends affecting demand for energy fuels: (1) rapidly growing commercial energy consumption spurred by the rapid pace of economic growth, industrialization, and improving living standards; (2) fuel substitution in industry and home use; (3) inability of energy fuel suppliers to keep pace with rising consumption; and (4) improved efficiency of energy fuel utilization, particularly in the industrial sector.

While China's energy consumption per capita is currently only one-sixth that of OECD countries, China's population growth and overall demography ensures significant continued pressure on energy demand. Currently eighty percent of residential energy consumption is provided by non-commercial biomass, mainly cropstalks and fuelwood. However, the expected increase in population from 1.2 to 1.6 billion people by 2030, a rural-to-urban migration with concomitant shift from non-commercial to commercial energy fuels, and improvement of living standards moving the entire population closer to the OECD norm of per capita energy consumption will severely impact energy demand.

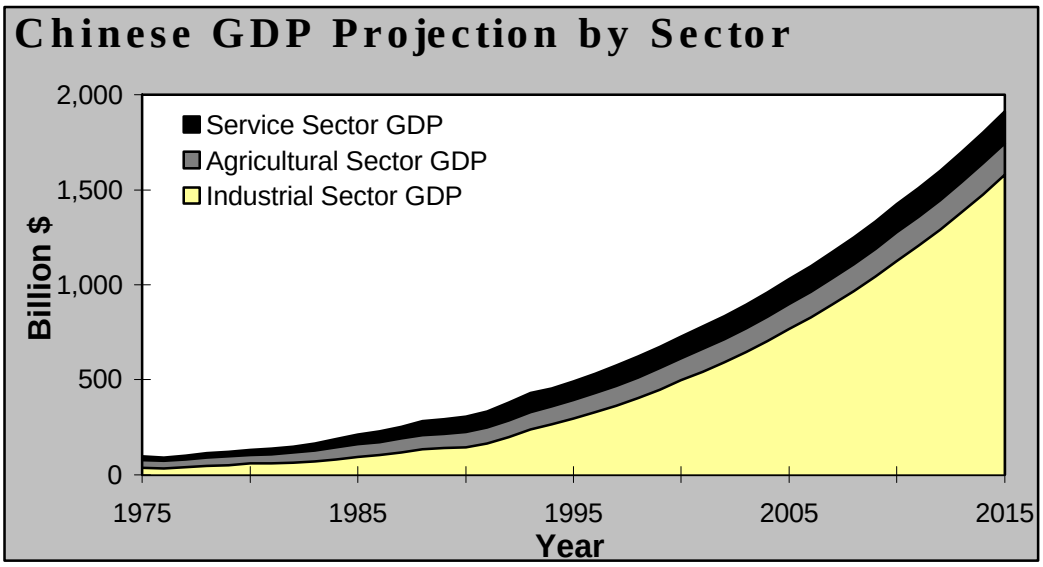

Figure 1

Source for historical data: The World Bank

Already, increases in the standard of living and have resulted in an influx of home appliances, accompanied by an increase in demand for new energy fuels such as electricity and natural gas as substitutes for coal. Meanwhile, rail traffic is saturated, resulting in more heavily traveled roads for both freight and personal transportation, significantly increasing traffic and motor fuels consumption. This demand for oil and gas from the residential and transportation sectors has

caused China to switch from a position of net exporter to net importer of these fuels within the last four years; while demand for electricity is so high that China operates electric power grids with standard load factors far above US operational norms.

Growth of energy consumption has been so rapid that in the fifteen years before 1994, total final energy consumption in China more than doubled to 640 million tons of oil equivalent (Mtoe), and it is expected to redouble by 2006. As China's most abundant and accessible energy source, coal made up 75% of the 1994 consumption (including coal used in electric power generation), with oil constituting 17.4 %, natural gas 1.9%, and hydroelectric power the remaining 5.7% (Figure 3). That same year (1994), industry accounted for 61% of the energy consumption by sector, while transportation held a 10 % and the residential/ commercial building sector held a 20% share. This composition has been relatively constant over the past ten years (Figure 2).

The aggregate efficiency of Chinese energy consumption has improved in recent years. However, energy consumption per dollar of gross domestic product (GDP) remains more than ten times higher than OECD countries. Thus, China has an opportunity to relieve some pressure on energy fuels demand by further increasing the efficiency with which energy is used. Studies show that 80% of the reduction in energy intensity, defined as the value of total energy consumption per unit of GDP (*see Methodology section*) between 1980 and 1985 was due to industry. Of this 80%, 91% is due to real efficiency improvement, and only 9% to structural changes (Levine, et al. 1992). China could do more. Although the government has promoted energy conservation and accelerated the supply of energy through the use of market mechanisms, energy use is still inefficient due to 1) high dependency on coal[1], 2) inefficient industry[2], and 3) incomplete price liberalization[3] (Ishiguro, et al. 1995).

B. METHODOLOGY

Chinese final energy requirements[4] are projected by sector and fuel type to the year 2015 using

[1] The average thermal efficiency of the coal boilers used in the industrial sector is estimated at 50 to 60%, while the efficiency of the oil and gas boilers used in industrialized countries is 80 to 90%. The thermal efficiency of coal stoves used in the household sector is estimated at only 20 to 25%. That of modern gas stoves is in the range of 55 to 60%.

[2] The industrial sector has been growing rapidly, and its share of final energy consumption in 1990 was 64%. But the sector has a high energy intensity because most industries are still using old equipment in smaller plants that preclude economies of scale. The amount of energy required to produce a unit of steel, cement, ammonia, or paper is considerably more than what is required in industrialized countries (sometimes twice as much).

[3] Although the government decided to liberalize most energy prices at consumer levels, mixed price formulas continue to exist during the current transitional period. Up to the early 1990s, energy prices were so low that enterprises had little incentive to try to conserve energy. Low prices also constrained the development of new energy supplies.

[4] Final Energy Consumption is a measure of the actual commercial energy consumed by the end users. It does not include the generation or transmission losses that are included in Total Primary Energy Consumption, nor does it include non-commercial biomass fuels.

the standard breakdown into industrial, transportation, and agricultural sectors. The traditional commercial and residential sectors are combined into a single buildings sector when reporting results.

An energy intensity model was used to generate the projection. Energy intensity is the ratio of aggregate energy consumption to some aggregate measure of economic activity, typically GDP. Thus energy intensity may be interpreted as a measure of how much energy was consumed in any given activity versus the expense of the activity (similar to efficiency). By examining the history of a sector's energy intensity and GDP, and projecting that development into the future, energy requirements can be projected as the product of the intensity and sectoral GDP.

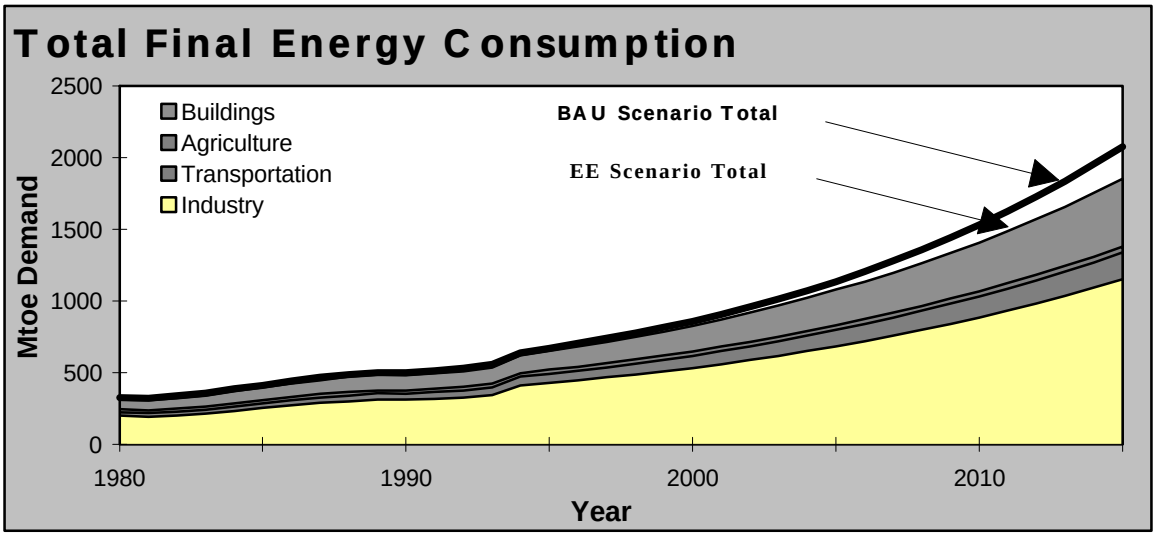

Figure 2

Source for historical data: IEA

Two scenarios are included in the analysis: a Business as Usual (BAU) scenario and an Energy Efficient (EE) scenario. The Business as Usual scenario projects future energy requirements based on current rates of development, assuming that past trends in consumption will continue. These trends were modified as necessary, by the following factors: 1) economic and social policies likely to affect future economic development and energy consumption; 2) trends in development and energy consumption for comparable countries at similar stages of development; and 3) trends in technology utilization and their implications for energy consumption. The Energy Efficient scenario assumes that the major consumption sectors of industry, transportation and buildings will reduce their energy intensity levels though increased use of energy efficient technologies. The agricultural sector was ignored for the EE analysis because the existing level of mechanization is so minimal that the BAU growth is considered to already be the most energy efficient option. In considering differences in fuel consumption, it is assumed that any reduction in demand between the BAU and EE scenarios will result solely in reduced coal consumption.[5]

[5] This assumption was made to match IEA data which indicates that current consumption efficiencies for hydropower, oil and natural gas resources are unlikely to be improved upon.

C. KEY FINDINGS

China is a large country in terms both of land mass and population, projected to grow 0.6% per annum (p.a.), during the next two decades. Given this population growth and industrialization/ modernization trends, energy consumption will increase substantially, as final energy requirements grow exponentially. We project the Chinese final energy requirement will grow by a multiple of 2.4 between 1994 to 2010 and 3.3 between 1994 to 2015, with average growth rates of 5% p.a. from 1994 to 2000, 5.9% p.a. from 2001 to 2005, 6.2% p.a. from 2006 to 2010, and 6.3% from 2011 to 2015. In other words, we project the Chinese final energy requirement will grow at an increasing rate in the next 20 years. A World Bank study projected Chinese energy demand will grow at an average rate of 6.5% p.a. while an IEA study projects energy demand will grow by a factor of 2.1 between 1993 and 2010, an average rate of 4.4% p.a. (Ishiguro, et al. 1995 & IEA 1996).[6] Our projections fall between the two.

Projected Energy Demand % Growth Rates					
Years	1994-2000	2001-2005	2006-2010	2011-2015	Demand in 2005
World Bank	6.5	6.5	n/a	n/a	1,267 Mtoe
IEA	4.4	4.4	4.4	n/a	987 Mtoe
BAU	5.3	6.0	6.4	6.6	1,136 Mtoe
EE	5.1	5.6	5.7	5.8	1,103 Mtoe

Table 1

1. The Business as Usual (BAU) Scenario:

Under the BAU scenario, China's total final energy requirement will increase by a factor of 3.3 to 2,077 Mtoe between 1994 and 2015, with a growth rates of 5.3% p.a. from 1994 to 2000, 6% p.a. from 2001 to 2005, 6.4% p.a. from 2006 to 2010, and 6.6% from 2011 to 2015 (Figure 2). In other words, we project that China's total energy requirement will grow in an increasing rate in the next 20 years.

The industrial sector will continue to be the largest energy user, but its share of final energy requirements will fall to 60% in 2015, down from the current value of 64% (Figure 2). Industrial energy intensity is assumed to continue decreasing at an ever decreasing rate as production shifts to high value-added and less energy intensive products, with anticipated improvements in technical and labor efficiency. Industry contributes 55% to the total GDP and it is assumed that the sectoral GDP will continue to grow faster than the total. Thus, the industrial sector will remain the dominant sector of the economy. It is projected that industrial final energy requirements will reach 1.24 billion toe (Btoe) in 2015.

[6] The IEA study assumes that energy prices increase as demand increases, that energy conservation efforts made by the Chinese government will continue, and that the energy intensity will continue to drop. The World Bank projection, on the other hand, assumes limited energy conservation and a limited shift of products from high energy-intensive to lower ones.

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Figure 3 *Source for historical data: IEA*

Though certainly not the largest energy consumer, the commercial building sector is projected to have the largest increase in growth; final energy requirement will increase to 7.3% of the total, up from 2.7%, by 2015 (Figure 2). The reason for this sector's fast growth is that service sector GDP, the activity measure for the commercial buildings sector, will grow 11.1% p.a. Therefore, the service sector will grow from 25% of the economy in 1994 to 39% in 2015. With this growth will come an increase in energy consumption, and it is projected that the commercial sector's energy requirement will reach 151 Mtoe in 2015 (Figure 7).

Residential energy consumption in China is dominated by coal and biomass. However, since biomass is not a commercial fuel, it is not considered in our forecast. In consumption of commercial fuels, rapid economic growth has brought about significant changes in the consumption pattern. Most significantly, household use of electricity increased more than four-fold from 1980 to 1990, due to the increasing use of electric appliances. We project that the residential sector energy requirement will continue to increase, reaching 357 Mtoe in 2015 (Figure 7).

China is unlike other countries because its transportation infrastructure is so limited that this sector, typically a major energy consumer, makes up less than 10% of the total final energy consumption. Road traffic grew at a much faster rate than overall transportation, 13.3% p.a. increase for passenger road traffic while road freight grew at double the rate of rail freight. As a result, road passenger traffic as a share of all passenger traffic increased from 32% in 1980 to 49% in 1994. The tremendous increase in road usage spurred a 5.2% p.a. growth in energy consumption in this sector, but this is well below the total GDP growth of 10% p.a. Therefore the transportation sector's energy intensity has been decreasing. We assume the transportation energy intensity will continue to decrease, at a rate of 2% p.a. until 2005, and then at 1% p.a. until 2015. The total energy requirement of this sector will reach 259.2 Mtoe in 2015 (Figure 12.).

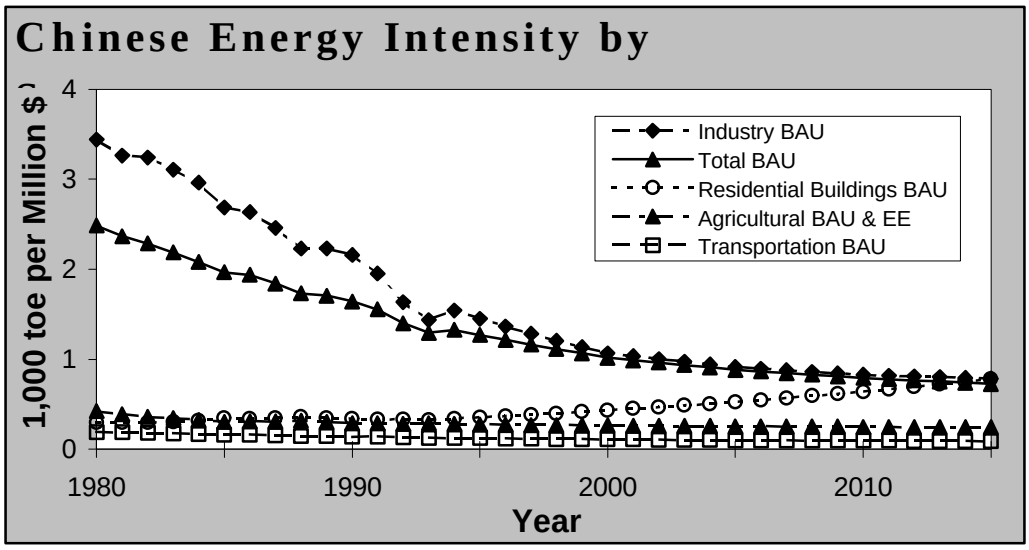

Figure 4 *Source for historical data: IEA, World Bank*

2. The Energy Efficient (EE) Scenario

Under the energy efficient scenario, total final energy requirement is projected to increase by a factor of 3.1 to 1,880 Mtoe with average growth rates of 5.1% p.a. from 1994 to 2000, 5.6% p.a. from 2001 to 2005, 5.7% p.a. from 2006 to 2010, and 5.8% from 2011 to 2015. In other words, even under the energy efficient scenario, we project that China's total energy requirement will still grow in an increasing rate in the next 20 years but will be slower than the BAU scenario.

Even under the EE scenario we don't expect the industrial energy intensity to drop much compared to the BAU scenario because the anticipated BAU 6% p.a. decrease is already a very high percentage for a developing country (IEA 1995). We assume the energy intensity will drop only 0.5% faster than the BAU scenario after the year 2000. It is estimated that under the EE scenario the industrial final energy requirement will reach 1.15 Btoe in 2015, just 95 Mtoe less than the BAU scenario. For the residential building sector, we assume the energy intensity increases 4% p.a. until 2005, just as it did in the BAU scenario, but then drops to 3% p.a. after 2005. With these constraints, the energy requirement will reach 324 Mtoe in 2015, 33 Mtoe less than the BAU scenario. For the transportation sector, we assume more steam locomotives will be replaced by more efficient diesel and electric locomotives, modern technologies will be imported to make the automobile fleet more efficient. This would allow the transportation sector energy intensity to decrease at a constant rate of 3% p.a. to 65 toe per million dollars in 2015[7], and the projected energy requirement will reach 186.9 Mtoe.

[7] Unless otherwise noted, dollars ($) in this text refers to constant 1987 US dollar value.

D. INDUSTRIAL SECTOR

Energy consumption in the industrial sector made up more than 61% of the total final energy consumption in China in 1993. The total industrial energy consumption increased from around 200 Mtoe in 1980 to 350 Mtoe in 1993. Currently, direct use of coal makes up almost 69% of all the final energy consumption, electricity 12.7%, and petroleum products 10.5%. The electricity share has been increasing quite rapidly while the share of direct use of coal has been gradually declining. The industrial energy intensity in 1993 was 144 toe/$ Million, much higher than the U.S. industrial intensity which was 52 toe/$ Million in 1970.[8] Energy intensity has been declining at an average rate of about 6% every year since 1980. However, at the same time the industrial GDP has been increasing at an average rate of about 10% every year.

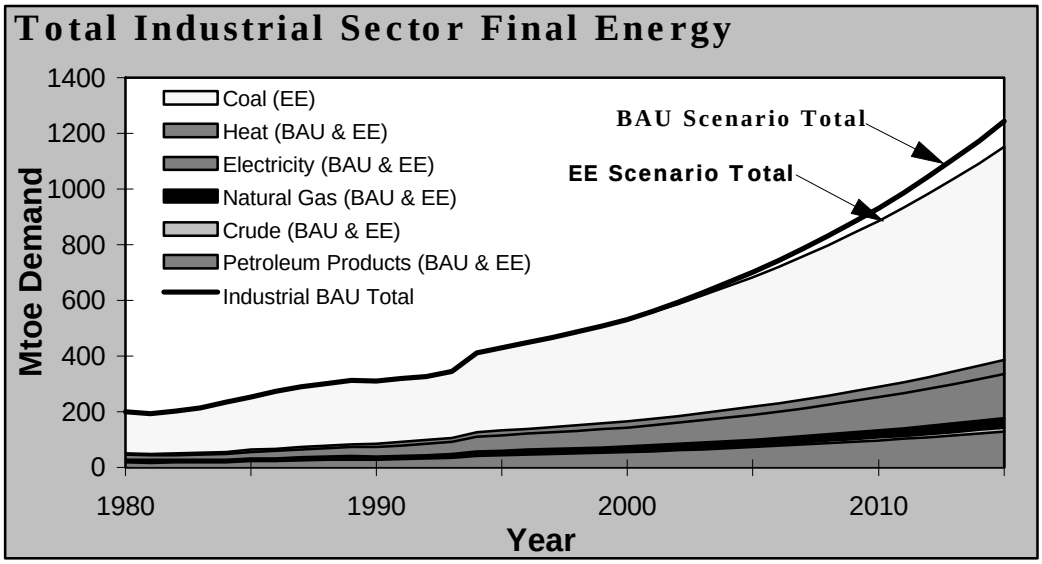

Figure 5 *Source for historical data: IEA*

Studies show that 80% of the reduction in energy-intensity between 1980 and 1985 is due to industry; of this 80%, 91% is due to efficiency improvement, and only 9% to structural change (Levine, et al. 1992). Because almost all energy savings in China occurred through efficiency gains in industry, the chemical, metallurgy and cement industries have been the major causes of China's reduced energy intensity in the early 1980s.

As indicated in the Ninth Five-Year Plan, adopted at the Eighth National People's Congress in March 1996, China intends to continue efficiency improvements through the restructuring of industry. Between the years 1996 and 2000, China will attach importance to the readjustment and optimization of the industrial structure, revitalizing pillar industries, and expediting the development of the tertiary sector (HKTDC 1995). The application of electronic information technology will be promoted, while the overall strength of the electronic industry is enhanced.

[8] The market exchange rate was used to convert Chinese Yuan to US$; if a PPP exchange rate were used, the energy intensity for China would be lower.

The electronics industry is intended to become one of China's pillar industries. Special attention will be paid to microelectronics, as well as digital, software, and network technologies.

1. Analysis of three industrial sub-sectors

The fertilizer, iron and steel, and cement industries are analyzed briefly as typical examples of Chinese industry to measure energy consumption efficiencies. They represent the three largest industrial sub-sector consumers of the chemicals, ferrous metals, and building material production industries.

1-a. China's Fertilizer Industry

The largest energy consuming industrial sub-sector is China's chemicals industry, typified by fertilizer production. Since approximately 90% of the energy used in fertilizer production is consumed for generating ammonia from the catalytic fixation of atmospheric nitrogen. In the early 1960s China introduced a process to produce ammonia and ammonium bicarbonate from coal. Although this process is very energy inefficient and creates a low grade ammonium bicarbonate nitrogen fertilizer, it satisfied China's needs at that time. Many small plants using this technology were constructed and about half of China's nitrogen fertilizer comes from the 1,000 or so of these plants still in operation.

The low production efficiency is attributed not only to plant size but also to the feedstock used for ammonia synthesis. Whereas 98% of the feedstock in the United States is natural gas , coal is still used as the main feedstock in China.[9] Due to the abundance of coal reserves in China, old, small, coal-based plants still play a major role in the fertilizer industry. Modernization of these plants is necessary. However, many of the existing plants throughout the country remain strategically important because China's transportation infrastructure is not sufficiently developed to provide effective transport of fertilizer from the larger plants to rural China (Ishiguro, et al. 1995).

In March 1996 China unveiled a 15-year blueprint for the country's chemical industry calling for the expansion of chemical plants and increased foreign investment in the sector. The focal point of the plan will be chemicals for agricultural use, including fertilizers, pesticides, plastic film, and feed additives. (HKSTD, March 29, 1996).

1-b. China's Iron and Steel Industry

In 1994, the iron and steel industry produced 92.1 million tons of crude steel and rolled out 84.3 million tons of steel products, as well as significant amounts of cast iron. Total final energy consumption was 72 Mtoe in 1990, including 55.6 TWh of electricity and 56.6 Mtoe in combustible fuels. The steel industry accounts for 20% of total industrial fuel use, 14% of total industrial electricity use, and is the second largest energy user in China's industrial sector.

[9] This high dependency on coal decreases the industry's overall energy efficiency. Coal-based ammonia production consumes about 35% more energy than gas-based with today's technologies.

Adjusted industry-wide, Chinese energy intensity in steel production was 35% higher than in the United States. Overall energy intensity has decreased with the reduced share of open hearth furnaces and increased use of continuous casting. However, some energy efficiency indicators have actually deteriorated in recent years as production from small plants increased[10]. The iron and steel industry in China has been targeted for energy conservation since the early 1980s, but due to the expense of conversion and the larger number of small plants, these plans have met with limited success (Ishiguro, et al. 1995).

China's crude steel production is expected to reach 172 million tons by 2005 and its potential imports of iron ore could reach 90 million tons compared to 37 million tons in 1993. China's iron ore imports are expected to rise to 56 million tons in 2001, while steel production is expected to rise to 95 million tons in 1996 (13% of world total) and to 114 million tons in 2001 (HKSTD, March 14, 1996).

1-c. China's Cement Industry

China is the world's largest producer of cement, generating about one-fifth of world total production. The 1990 output of 210 million tons doubled to 421 million tons by 1994. As with most Chinese industries, the bulk of production, 70%, is from small, inefficient, low capacity plants.

The cement industry consumed about 29 Mtoe of energy in 1990, accounting for 7% of total industrial final energy use. The two primary sources of energy were coal (77%) and electricity (23%). Energy accounts for about 40% of total production cost in China's cement industry, a dramatic indicator of the industry's inefficiency. Industry-wide fuel intensity for clinker making (the material ground into cement) is about 126 kg of oil equivalent (kgoe)/ton of clinker, whereas that of Japan s industry is 71 kgoe/ton of clinker.

Modernizing China's cement industry has been a unique endeavor because of the presence of so many inefficient vertical kilns. Conservation measures adopted by the industry in the 1980s included comprehensive retrofit of vertical kilns[11], conversion of wet process kilns to semi-dry or dry process kilns, and the introduction of large-scale precalciner kilns. Inefficient small plants were closed and wet and dry process kilns were also retrofitted (Ishiguro, et al. 1995).

2. Industrial Sector: Business As Usual Scenario

Industrial sector energy intensity is assumed to continue decreasing as it has for the past fifteen years, but at an ever decreasing rate. For the next five years, until 2000, energy intensity is

[10] The industry average of the coke equivalent rate (fuel used to produce pig iron) rose from 605 kg/ton of pig iron to 611 kg/ton of pig iron between 1985-1990, and the industry average of electric arc furnaces (EAFs) intensity rose from 626 kWh/ton of crude steel to 689 kWh/ton of crude steel during the same period

[11] Advanced vertical kilns (VK) have a fuel intensity of about 88 kgoe/ton of clinker. The best-operated mechanized VKs can reach a fuel intensity of 77 kgoe/ton of clinker and an electricity intensity of less than 110 kWh/ton-of-cement. These figures indicate great potential for energy conservation in VK-equipped small plants, which now have an average fuel intensity of about 115 kgoe/ton of clinker.

assumed to decrease at the current rate of 6% p.a. From 2000 to 2005 it is assumed to decrease 3% p.a., 2% p.a. from 2006 to 2010, and 1% p.a. from 2011 to 2015 (Figure 4).

The energy intensity will keep decreasing for three major reasons. Improvements in technical efficiency, and changes in the relative output of major industries, including a shift from heavy to light industry. Also, China is starting to use its labor resources more wisely, increasing labor efficiency instead of merely relying on the large volume of the available labor pool. In other words, China intends to manufacture high value products that require small amounts of energy to produce. The rate of improvement is expected to drop as these changes take place and the desired efficiency is achieved.

Chinese Industrial Development		
EFFICIENCY IMPROVEMENTS	SHIFT TO LIGHT INDUSTRY	BETTER USE OF LABOR
• New boilers • Better electric motors • Computerized process control	• Move to electronics from heavy machinery production	• Reduce dependence on labor pool volume • More efficient use of labor

Table 2

China will renovate traditional industries by upgrading 70% of all industrial boilers and high consumption electric motors. Efficiency increases are expected from computer control of both process, to be introduced in 14,000 factories, and through use of computers to improve labor efficiency. In medium and large sized enterprises, computer aided design will be used in 70% of the designing work, while in a simultaneous effort to improve finances, computers will be introduced to manage more than 5,000 additional plants. Lastly, a shift in production is expected to cause the heavy to light industry ratio to drop from 57:43 to 50:50 as the electronics and communications industries grow.

We assume the intensity will decline to 787 toe/$ Million[12] by the year 2015 (still higher than the U.S. industrial energy intensity in 1973, which was 500 toe/$ Million). We assume the industrial GDP will grow at an annual rate of 11% until 2000, and 9% p.a. from 2001 to 2005, 8% from 2006 to 2010, 7% from 2011 to 2015 (Figure 6). Industrial GDP is assumed to grow faster than total GDP because industrial GDP made up over 55% of the total GDP and with all these efforts in developing the industrial sector, it will remain the leading sector of the future economy in China. Growth in industrial GDP and reductions in energy intensity imply that the industrial final energy requirement will increase and reach 1.24 Btoe in 2015 (Figure 5).

3. Industrial Sector: Energy Efficient Scenario

Under the EE scenario, we expect the energy intensity to drop about the same as in the BAU scenario, because the BAU 6% p.a. decrease is already very high for a developing country (IEA 1995). Therefore, we assume that under the EE scenario the energy intensity will decrease at the BAU rate of 6% p.a. until the year 2000. From 2000 to 2005, it is assumed to drop 3.5% p.a.,

[12] Unless otherwise noted, all dollar amounts are in constant 1987 dollars.

2.5% p.a. from 2006 to 2010, and 1.5% p.a. from 2011 to 2015. This is only 0.5% faster than in the BAU scenario. Industrial GDP is assumed to growth the same rate as it is in the BAU scenario. Thus, under the EE scenario, the industrial final energy requirement will reach 1.15 Btoe in 2015, 95 Mtoe less than the BAU scenario (Figure 5).

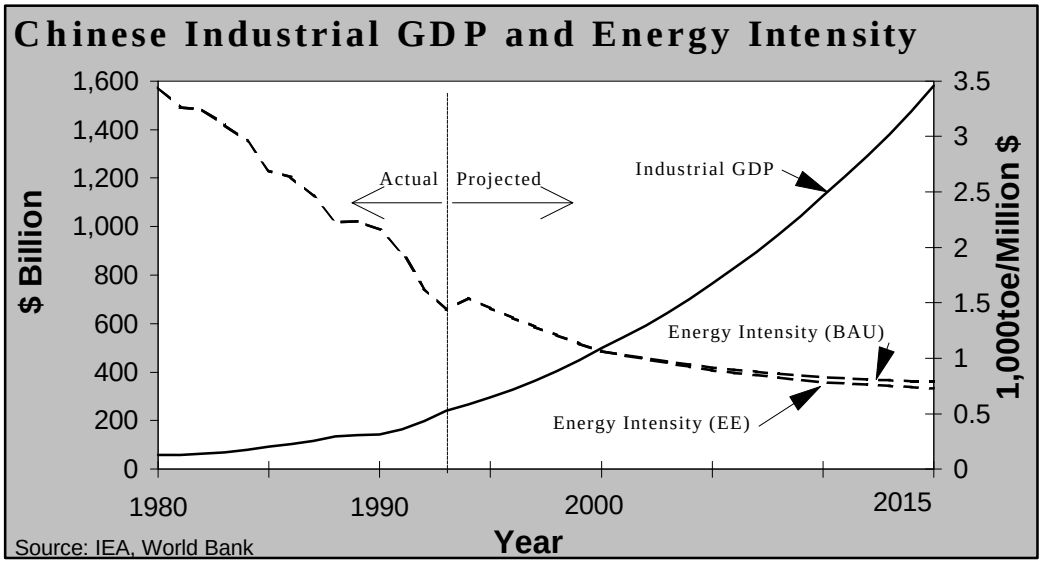

Figure 6

Source for historical data: World Bank, IEA

E. BUILDING SECTOR

Total building energy consumption increased from around 67 Mtoe in 1980 to about 113 Mtoe in 1993 and made up more than 20% of the total final commercial energy consumption in China. It is second only to the industrial sector in terms of energy consumption (Figure 2). Of the 20%, over 87% (98.6 Mtoe) was for residential buildings, excluding biomass.

Although the commercial and residential sectors have been combined in our treatment of the building sector, the two have very different fuel consumption characteristics. Household, or residential energy consumption is predominantly fuels for cooking and space heating, while commercial consumption shows a higher dependence on the petroleum products and electricity needed to run a modern business. In residential consumption, seventy percent of the population lives in rural areas where commercial fuels are scarce; up to eighty percent of the residential fuel use is non-commercial biomass, mostly crop stalks and firewood (Ishiguro, et al. 1995). So much non-commercial fuel is used in the residential sector that biomass use in 1993 was over 54 Mtoe, three times as much as the energy used in commercial buildings (LBL 1996).

In urban areas where commercial fuels are more accessible, coal dominates the residential energy market. However, with rapid economic growth, urban energy consumers have begun to use electricity both to run new appliances and as a coal substitute. Consequently, household electricity demand increased five-fold from 1980 to 1993. In 1993, direct use of coal made up

over 85% of the energy used in the residential building sector, electricity 8%, and petroleum products 4%. The use of fuel for the commercial building sector is very different. Direct use of coal made up less than 35% of the energy used in the commercial building sector while electricity made up over 40%, and petroleum products more than 25%.

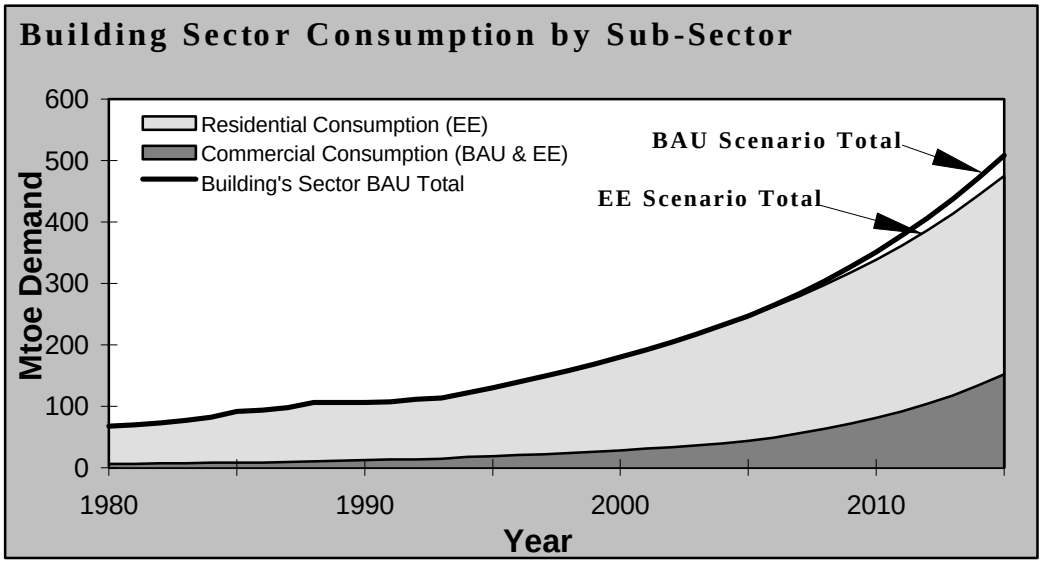

Figure 7 *Source for historical data: IEA*

Gas fuels for cooking (about half being LPG) are much more accessible in urban Chinese households, with nearly 60% of residents in cities now having access. The rate of gas fuel consumption has been rising as fast as electricity, as cities nationwide push to improve the efficiency and cleanliness of household cooking fuel use. LPG demand growth, concentrated in the coastal area south of the Yangtze River, has made China a net importer. Gas fuels are still virtually unavailable in rural areas (LBNL, 1996).

Possession of Appliances per 100 households in 1994		
Appliance Type	**Urban Household**	**Rural Household**
Electric Fan	153.79	80.91
Color TV Set	86.21	13.52
Refrigerators	62.10	4.00

Table 3 Source: *China Statistical Yearbook 1995*

There are significant differences in the quality of energy service between rural and urban households, sharply differentiated into those who have electricity and those who have not. While urban households have adequate fuel supplies and access to electricity, many rural areas still suffer from fuel shortage. About 40 million rural households, out of 232 million, have no access to electricity. Per capita fuel consumption in rural areas is higher than in urban areas because of inefficient use of biomass, while per capita electricity use in urban areas is four times as much as their rural counterparts from much higher rates of appliance use.

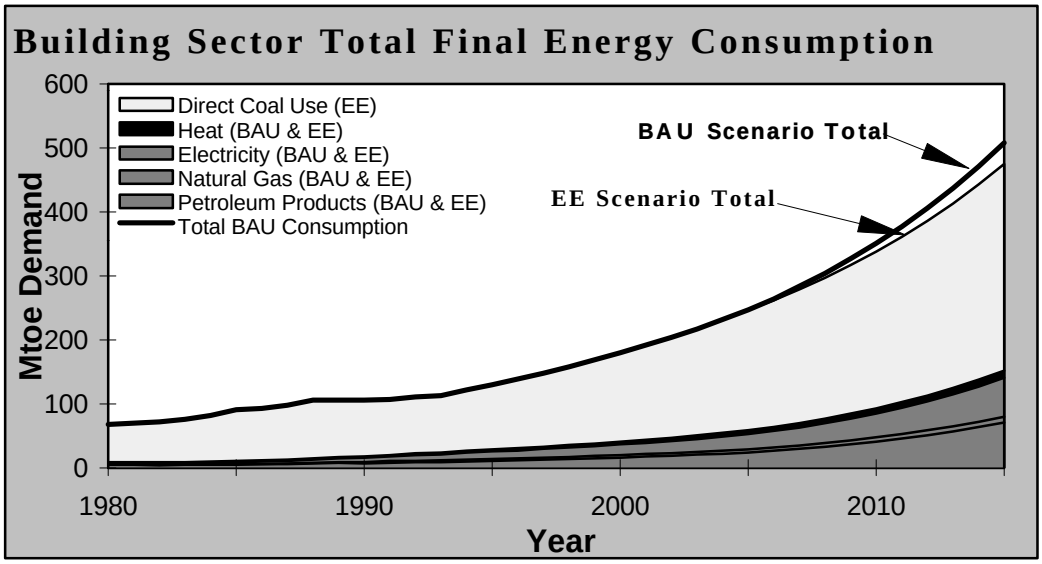

Figure 8 *Source for historical data: IEA*

According to the Ninth Five-Year Plan, China will accelerate the establishment of large regional electric power grids in accordance with the development strategy of transmitting power from central to eastern China, laying the foundation for the formation of a national grid (HKTDC 1995). It is likely that when electricity is more readily available to the households in the rural areas, electricity demand in the residential sector will increase significantly.

1. Buildings Sector: Business As Usual Scenario

Residential building energy intensity is defined as energy used (commercial energy, i.e. excluding biomass) divided by the number of households. In 1993, the energy intensity was 0.33 toe/household and has been increasing steadily over the years (Figure 10). One would expect once households have basic appliances such as lighting, fans, TV sets and cooking ranges, the energy intensity will level off. However, China has a huge rural population; their basic needs are not yet met. Therefore, when electricity is made available to them, more basic appliances will be added to the households and electricity consumption will increase to the point where all available supply is in use; hence, the energy intensity increase in rural areas will offset any urban decreases.

Commercial building energy intensity is defined as total energy used in the commercial sector, divided by service sector GDP. In 1993, the energy intensity was 142 toe/$ Million, and has been slowly decreasing. The service sector in China is growing rapidly, even faster than the industrial sector, at a rate of over 11% in 1993. The growth rate of the service sector is faster than the growth rate of energy consumption, thus, energy intensity is decreasing (Figure 9).

In our BAU scenario, we assume residential energy intensity increases at a rate of 4% p.a. until the year 2015 with a constant 7174 households added per annum. For demand forecasting, the projected number of households is used rather than a sectoral GDP as an activity measure. In 2015, the projected energy intensity will be 0.78 toe/household (Figure 10). The U.S. residential

energy intensity in 1980 was 2.25 toe/household. It is projected that the residential sector energy requirement will reach 357 Mtoe in 2015 (Figure 7).

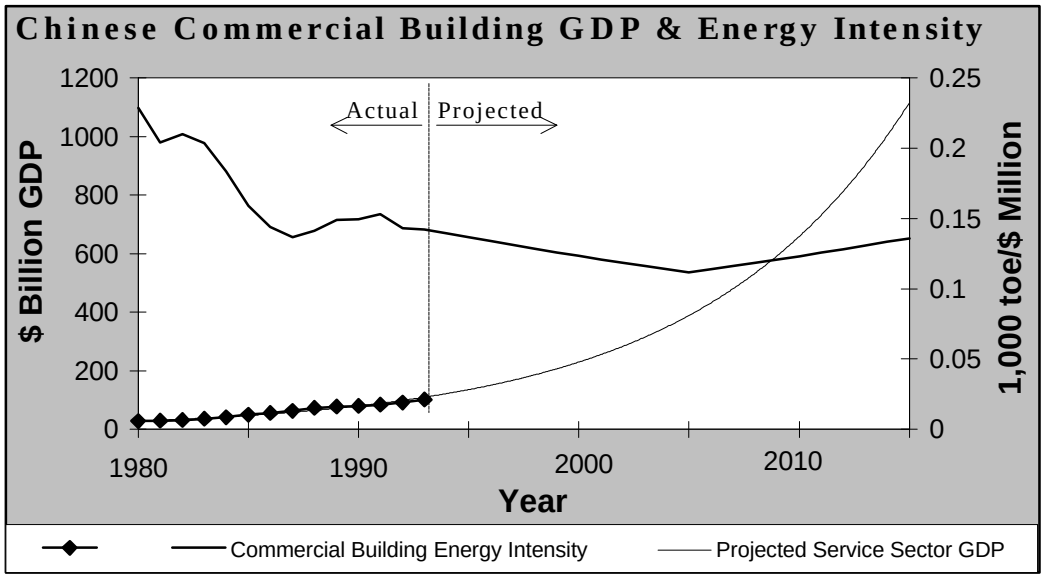

Figure 9

Source for historical data: World Bank, IEA

For the commercial buildings sector, service sector GDP will grow 11.1% p.a. It is assumed that commercial energy intensity will decrease 2% p.a. until 2005, after which the intensity will increase 2% p.a. (Figure 9). This reversal of trends is ascribed to the theory that as an increasing number of service sector businesses open, and the service supply catches up with demand, the value of services provided by the commercial sector will not grow more slowly than in the recent past. Thus, energy intensity will increase as operational costs rise through the addition of electronic office products such as copiers and computers, while the value of the services remains constant. Given these fluctuations, the commercial building energy requirement will reach 151 Mtoe in 2015 (Figure 7).

2. Buildings Sector: Energy Efficient Scenario

In our EE scenario, residential energy intensity increases by 4% p.a. until 2005, just as in the BAU scenario, but then the growth rate drops to 3% p.a. after 2005. The household growth rate remains constant at 7174 p.a. for both the BAU and EE scenarios. Under the energy efficient scenario, energy intensity will increase to 0.71 toe/household and the energy requirement will reach 324 Mtoe in 2015, 33 Mtoe less than the BAU scenario (Figure 7).

Commercial buildings account for less than 3% of the total final energy demand in China in 1993, which is insignificant compared to other sectors. Thus energy-efficient commercial appliances will not make much difference to the total future energy requirement in China, and the EE scenario is assumed to be the same as the BAU scenario for commercial buildings at 151 Mtoe.

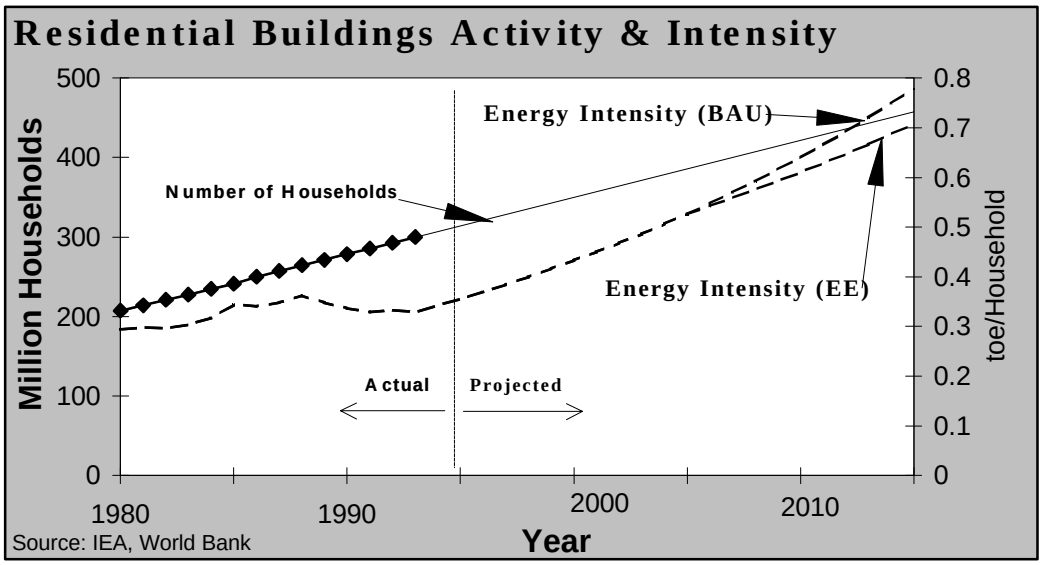

Figure 10 *Source for historical data: World Bank,*

F. TRANSPORTATION SECTOR

Energy consumption in the transportation sector made up less than 10% of the total final commercial energy consumption in China in 1993, just one-sixth of the industrial sector's total (Figure 2). Of this, the majority is for road transportation (65%), while less than 3% was for air transportation and slightly over 3% was for domestic waterway navigation. The remainder was used for rail transportation (Figure 11).

This amazingly low percentage of the transportation sector energy consumption is a direct consequence of Mao's "Country Planning" in the 1950's. Fearing invasion by the Soviet Union, Mao spread Chinese industries to isolated villages, with minimal road connections. Each of these isolated villages was intended to be self-sufficient. Long-distance transportation has only recently become a priority.

The total transportation energy consumption more than doubled to 56 Mtoe between 1980 and 1993. The average energy consumption growth rate of the transportation sector was 5.2% p.a. between 1980 and 1993, and thus was higher than the growth rate of total final energy consumption (4.7% p.a.) but was a lot lower than the average 10% p.a. GDP growth rate. Therefore, transportation sector energy intensity in China has been decreasing.

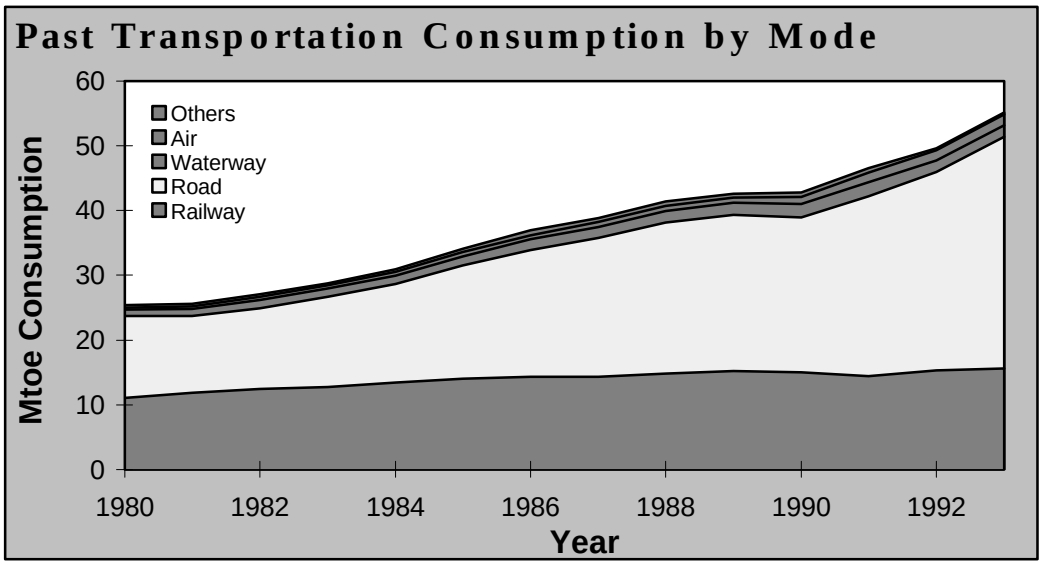

Figure 11 *Source for historical data: IEA*

1993, petroleum products made up over 78% of all the final energy used in this sector (coal made up 18.7% and electricity made up 2%) (Figure 12).

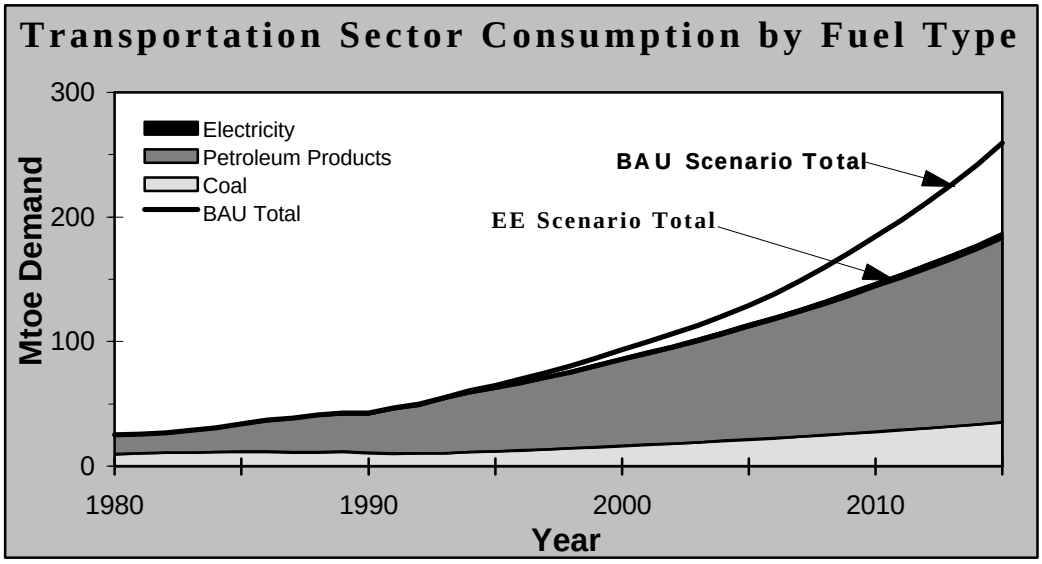

Figure 12 *Source for historical data: IEA*

1. Road Transportation

The energy consumption of road transportation increased to 35.9 Mtoe in 1993, the growth rate being a substantial 7.5% p.a. between 1985 and 1994. However, the energy efficiency of road transportation in China is increasing; during the 1980s almost all of China's domestic car makers imported modern technologies from western auto-makers through technology transfer agreements.

The growth rate of cars in use was more than 20% p.a. between 1985 and 1994. The total number of motor vehicles, estimated at 3.2 million in 1985, is projected to quadruple by the year 2000. China's demand for all kinds of motor vehicles will increase steadily over the next five years, at an average annual growth rate of 7 to 8 % (HKSTD, April 8, 1996).[13]

According to the Ninth Five-Year Plan, China is expected to manufacture 2.7 million new automobiles by the year 2000, which will meet 90% of the domestic demand.[14] It is estimated there will be a market for about three million cars by 2000, with demand reaching five to six million by 2010. (HKSTD, March 15, 1996). However, recent reports show that China's automobile production, aimed at private ownership, is faltering. Due to the expense, the vast majority of cars are being bought with state money. Of the 1.6 million cars on China's roads, only 50,000 cars or 3% are owned by private individuals. With newly imposed caps on state automobile purchases, analysts fear that the private car market will not live up to expectations as private sector purchases cannot make up for the shortfall in public spending, due to high prices, high license fees, and legal restrictions on ownership[15] (HKSTD, April 19, 1996).

2. Railway Transportation

Between 1978 and 1994, the total length of China's railway track increased from 48,000 km to 53,992 km, with the length of double-tracked railways expanding from 7,630 km to 16,159 km, and that of electrified railways from 1,030 km to 8,966 km. The volume of passengers increased by a factor of 2.6 between 1980 and 1994, while freight volume increased by a factor of 2.2. In 1994, the railways carried 1.89 billion passengers and 1.57 billion tons of cargo.

The replacement of old steam locomotives with diesel and electric locomotives was promoted strongly during the late 1980s. By 1993 the combined capacity of electric locomotives was over 7 GW, compared to less than 2 GW in 1986 (LBNL 1996).

As steam locomotives have been retired and replaced with new engines, the pattern of rail energy consumption has changed. Electricity and oil consumption doubled as diesel and electric engines became more common. However, coal still dominates fuel consumption at 66%, compared to 27% for oil and 7% for electricity.

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[13] By the year 2000, annual demand is forecast at three million vehicles while local output is expected to amount to only 2.7 million.

[14] To attain the target, emphasis would be placed on the development of auto parts and components, economy cars, and heavy-duty trucks.

[15] The cost of license plates in the city, sold at auctions, was almost the same as that of a private car. The high cost of the license plates aims to control private purchase of cars on the streets of Shanghai and other major cities, which are already crowded with bicycles, buses, motorcycles, and trucks. License plates in Shanghai for any private car costs about 140,000 yuan, while a four-seater Santana costs about 170,000 yuan and a Daihatsu Charade about 100,000 yuan. The average Shanghai worker earned 9,242 yuan in 1995, an inflation-adjusted increase of 5.2% on 1994.

3. Air Transportation

Boeing estimates that China will have the world's largest rate of air travel growth, an average of 11.5% annually over the next 20 years. In its latest aviation market outlook, Boeing said the worldwide average rate of increase for the same period was 5.1%. Travel in the Asia-Pacific region is expected to grow the fastest at 7.1%. By 2015, Boeing predicted traffic in Asia would be equal to that of North America as both regions post an average annual growth rate of 7.1% (HKSTD, March 8, 1996).

4. Transportation Sector: Business As Usual Scenario

The transportation energy intensity (total consumption divided by sectoral GDP) has been decreasing at an average rate of 3.5% p.a., despite the fact that energy consumption in this sector has been growing at a rate of 5.2% p.a. and the sectoral GDP grows much faster at a rate of 10% p.a. We assume the transportation energy intensity will continue to drop at a decreasing rate; 2% p.a. until 2005, and 1% p.a. until 2015. This projection puts the transportation sector energy intensity at 90 toe/$ Million and the total energy requirement at 259.2 Mtoe in 2015 (Figure 12 & 13).

5. Transportation Sector: Energy Efficient Scenario

Under the EE scenario, we assume a larger fraction of currently operating steam locomotives will be replaced by diesel and electric engines, and that implementation of modern technologies will make the automobile fleet more efficient. Therefore, in the EE scenario, energy intensity will decrease at a constant rate of 3% p.a.. This projection puts the transportation energy intensity at just 65 toe/$ Million and the projected energy requirement at 186.9 Mtoe in 2015 (Figure 12 & 13).

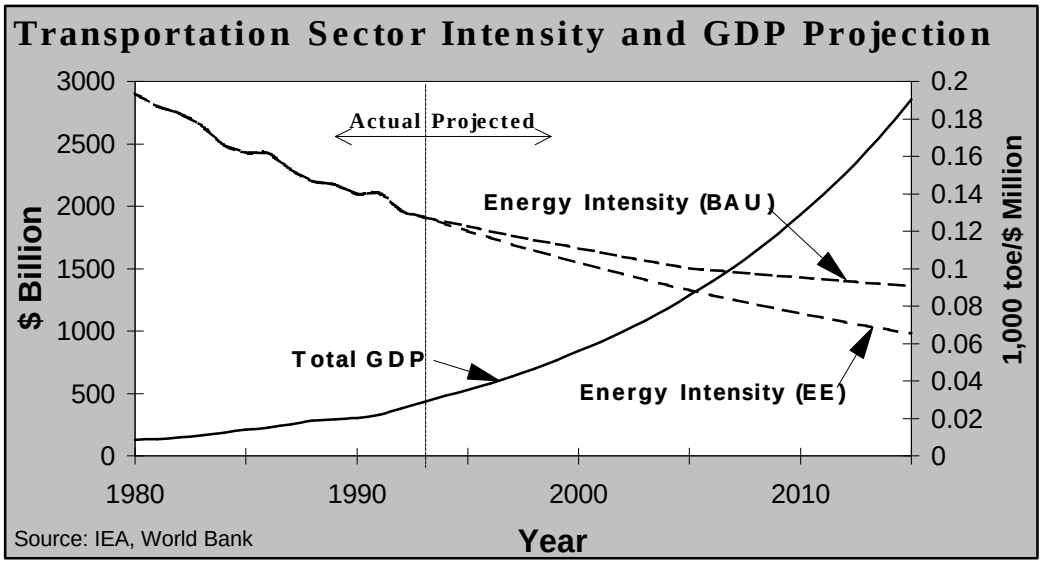

Figure 13 *Source for historical data: World Bank, IEA*

G. AGRICULTURAL SECTOR

Agriculture is the smallest sectoral user, consuming less than 5% of the total final commercial energy in 1993. Direct use of coal made up almost 44.5% of the total final energy used, with petroleum products and electricity being the only other fuel sources at 37.6% and 17.9% respectively. Electricity has been gradually replacing direct coal consumption, and its share has been increasing.

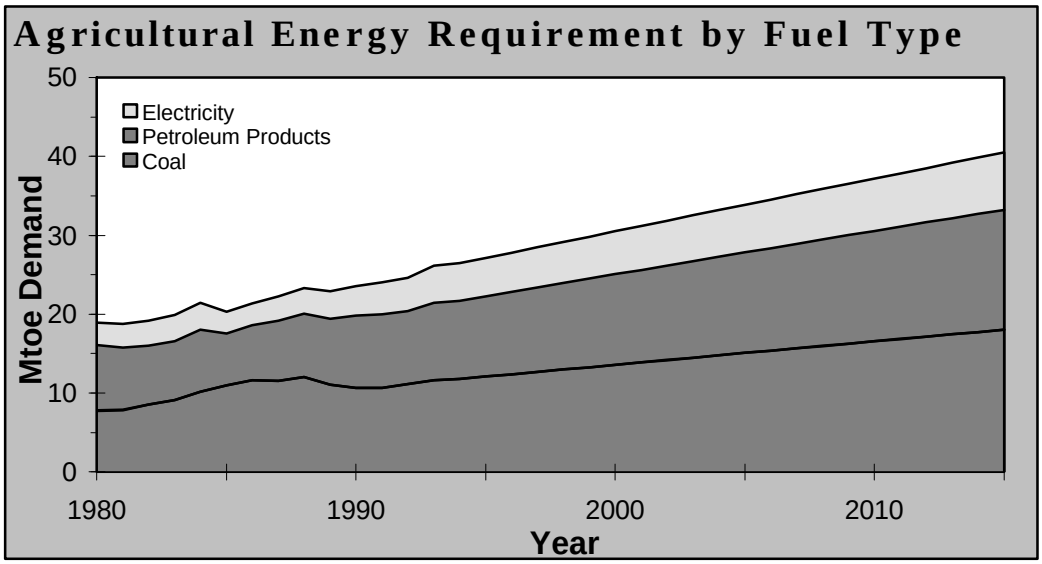

Figure 14 *Source for historical data: IEA*

China has been sacrificing farmland to industry, and is facing a serious food supply problem. With its grasslands already overgrazed beyond their sustainable capacity, livestock must be fed grain, pushing grain demand up dramatically.[16] In fact, China has become the world's largest wheat importer[17] (HKSTD, April 1, 1996). Further, as food imports become accessible, the Chinese are switching from their traditional grain-based diet to one based on meat and dairy products, making China the new world leader in the consumption of pork (Worldwatch Institute, 1995). The Worldwatch Institute has said that by 2030 China could face a deficit of between 200 and 365 million tons in grain needed to feed 1.6 billion people by that time, warning that this would put severe strains on international stocks.

[16] If per capita grain consumption rises from just under 300 kilograms in the mid-1990s to 400 kilograms in the year 2030, about the current level in Taiwan, total demand will climb more than 79%.

[17] Last year, China imported 11.59 million tons of wheat, and purchased more than half a million tons in January 1996 alone. As China's target for wheat harvest this year remains at last year's level, the International Grains Council projected Chinese wheat imports to 14 million tons for the July 1996 to June 1997 season, a rise of one million tons from 1995-1996.

Chinese officials say their primary strategy in the 1990s will be to raise yields on less productive land by increasing the use of fertilizer and high-yield seeds. Moves to protect arable land from encroachment by industrial development will be intensified, reserves of farm products built up, science and technology applied to optimize yields, side-line industries developed, product varieties adjusted, and overall rural reforms deepened (HKSTD, March 8, 1996).

China hopes to squeeze out badly needed gains in agricultural efficiency by increasing mechanization and encouraging coordination among farms. While efforts to boost output have focused in recent years on easy credit and other incentives, the emphasis now will be on aiding grain production centers and the farm machinery sector.[18] (HKSTD, March 4, 1996).

1. Agriculture Sector: Business As Usual Scenario

Although the Chinese government is working to mechanize their agricultural sector, heavy machines may not work well in small farms. China's millions of tiny family farms average only 0.46 hectares in size each, so large scale western mechanization techniques have limited applicability. Moreover, urban industrial salaries are growing much faster than farm earnings, and there has been a mass migration of peasants leaving their farms for the cities.

Crime rates increased significantly in all Chinese cities in recent years because of these unemployed peasants, and the crimes committed are becoming more and more serious. Fighting the crime rate has become another "priority" in the Ninth Five-Year Plan. Therefore, in the coming years, Beijing would need to either find work for these peasants in the cities or keep them on the farms. Currently, over 54% of the labor force in China are farmers. With this huge labor force and the social reasons to keep peasants on farms, the practicality of mechanizing the agricultural sector remains to be seen.

Since the agricultural energy demand accounted for less than 5% of China's total final energy consumption in 1993, no reasonable scenarios would have any significant impact on the total energy requirement projection. Therefore, we fit a regression line to the historical data to the project the future energy intensity and agriculture GDP. The result shows agriculture GDP will grow $3.4 billion p.a. and the energy intensity will decrease at a decreasing rate from 0.94% in 1994 to 0.44% in 2015 (Figure 15). Thus, projected energy requirement for the agricultural sector will increase from 26.5 Mtoe in 1994 to over 40.5 Mtoe in 2015 (Figure 14).

2. Agriculture Sector: Energy Efficient Scenario

[18] The State Council, China's cabinet, issued an eight-point decree calling on officials nationwide to help farmers carry out their spring planting to assure a good 1996 harvest. China, crisscrossed with millions of tiny, inefficient family farms averaging only 0.46 hectares each, set up the grain production center system in 1983 as a means of streamlining agricultural output. The centers help organize individual farms, providing technical training and field management and sponsoring seed reserves and breeding projects. Only 38% of China's farms are affiliated with the centers, which account for 46.6% of total grain output and produce an average of 0.8 of a ton more per hectare than the national average.

We assume the EE scenario is the same as the BAU scenario because China is still in an early stage of mechanizing its agriculture sector. Even if we assume china were able to successfully mechanize its farms in the next 25 years, primary effort will have to be focused on increasing production. Moreover, machines are an expensive capital investment and once they are purchased, it will take some time before they will be replaced with more efficient equipment again.

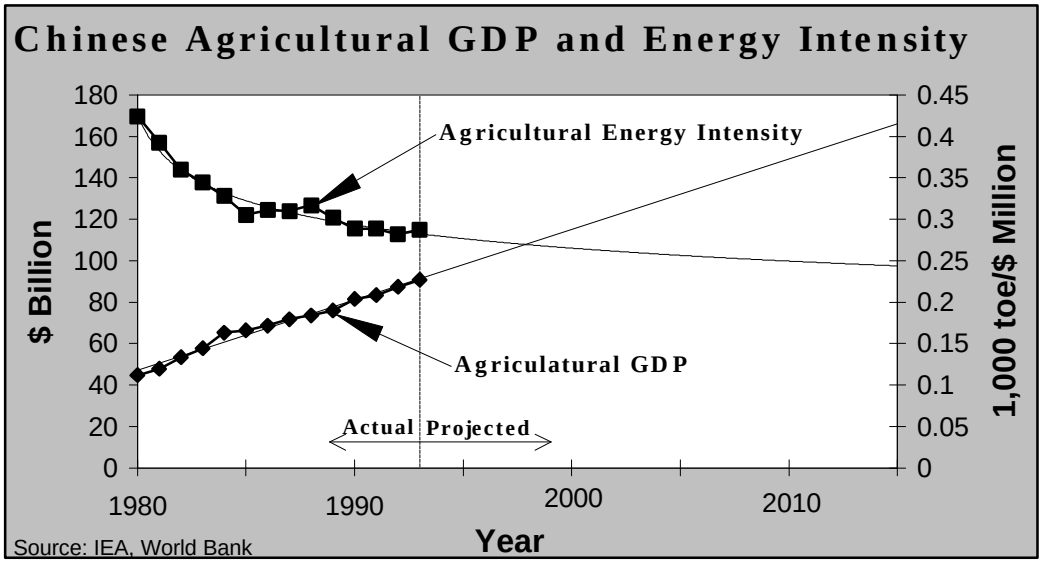

Figure 15 *Source for historical data: World Bank, IEA*

H. OTHER USES SECTOR

Energy consumption for other uses made up less than 3.6% of the total final energy consumption in China in 1993 (Figure 5) and is not identified as a sector in Figure 1. The total "other" energy consumption increased from 13.9 Mtoe in 1980 to about 20 Mtoe in 1993. Direct use of coal made up almost 52.5% of all the final energy used in this sector, petroleum product 45.5% and heat 2% (Figure 16).

1. Other Users: Business As Usual Scenario

Again, since the other uses sector accounted for less than 3.6% of China's final energy consumption in 1993, it is unreasonable to assume that this sector will have any significant impact on the total energy requirement projection. Therefore, the forecast was made by fitting a regression line to the historical data to get the projection for energy intensity. Energy intensity here is defined as the energy consumption divided by total GDP. The result shows energy intensity will decrease 7% p.a. The total GDP is assumed to grow 10% p.a. before 2000 and gradually grow at a decreasing rate (Figure 17). Therefore, the projected energy requirement for the others sector will increase from 20.8 Mtoe in 1994 to over 26.9 Mtoe in 2015 (Figure 16).

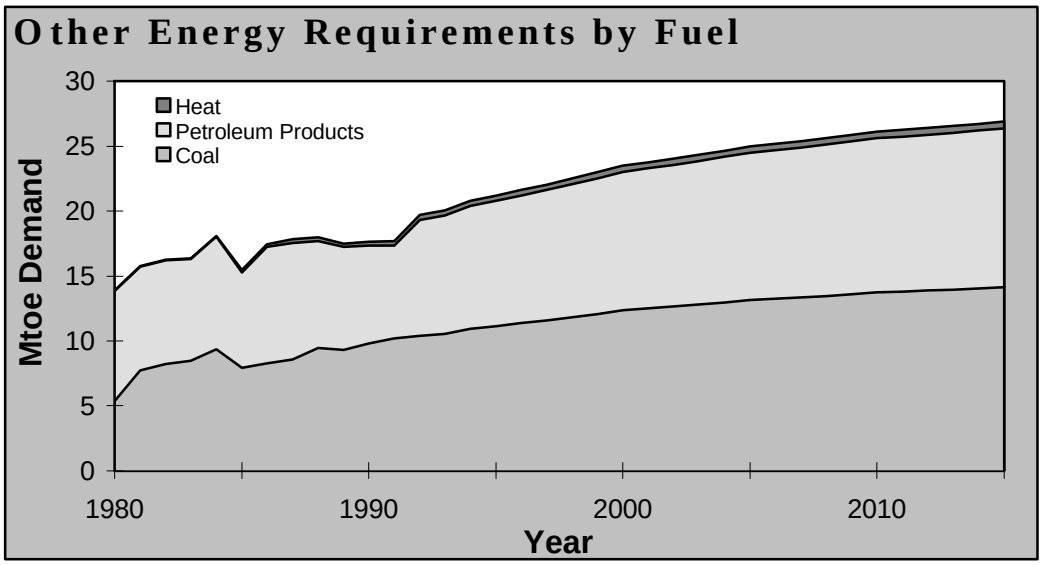

Figure 16

Source for historical data: IEA

2. Other Users: Energy Efficient Scenario

We assume the EE scenario is the same as the BAU scenario. As mentioned above, the others sector energy demand accounted for less than 3.6% of China's final energy consumption in 1993, improvement of energy efficiency in this sector is not expected to have any significant impact on the total energy requirement projection.

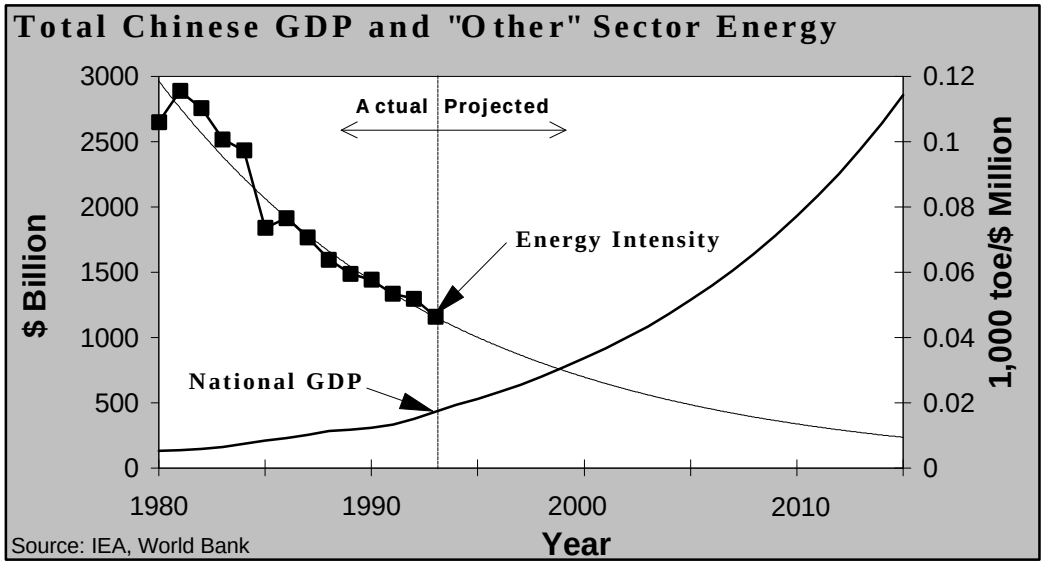

Figure 17

Source for historical data: World Bank, IEA

I. CONCLUSIONS

Chinese final energy requirements will reach between 2,853 Mtoe (BAU) and 2,581 Mtoe (EE) in 2015, depending on which scenario is considered. However, the structure of energy fuel consumption will remain relatively unchanged, despite the demand for new energy sources in urban areas and an increased production of electricity. As now, the majority of consumption will be in the industrial sector, followed by the consumption in buildings and transportation. Coal will remain the dominant energy source at 64%, followed by oil at 27% and natural gas at just under 4 %. What will change dramatically is the total consumption, up 334% from 1994. This increase will severely strain domestic energy resource supplies, and if China chooses to import resources in an effort to compensate, the volume of imports may cause increases in world energy prices, and indirectly affect US energy security (*see Summary, Section I).*